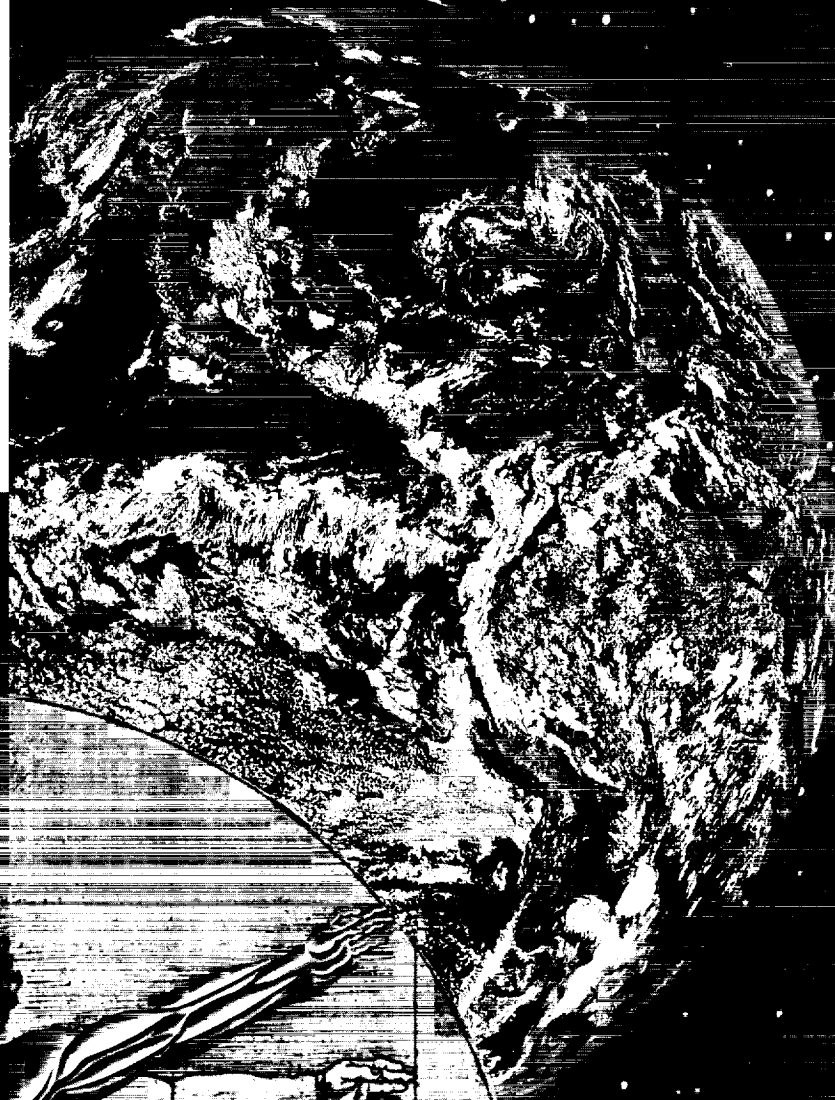


8-911
**Life and
Biomedical
Sciences and
Applications
Division**



**Life Sciences
Accomplishments
'94**



Rodney Ballard
(1942 - 1993)

whose commitment to excellence in the
space life sciences and leadership in
furthering international cooperation
continues to guide our efforts.

FOREWORD

The year 1993 was dynamic and productive for NASA space life sciences. We progressed significantly toward our goals of understanding the role of gravity in living systems and using the resulting knowledge to improve the health and quality of life of people on Earth. Life sciences research encompassed the gravitational range from the microgravity of space to the hypergravity provided by centrifuge facilities on the ground. It included exciting advances in our knowledge of space and an improved program of supporting ground-based research. The Spacelab Life Sciences 2 flight set records both in duration and in the quantity and quality of science accomplished. The Cosmos 2229 mission in January, which carried U.S. experiments on the Russian biosatellite (Bion 10), and our participation on the German-sponsored Spacelab Deutsche 2 Shuttle mission in April were scientifically successful and serve as building blocks for expanding international cooperation in space life sciences research.

The formation of the Office of Life and Microgravity Sciences and Applications early in the year—with a life scientist at the helm—reemphasized the importance of life sciences in the space program. As an integral member of this new organization, the Life and Biomedical Sciences and Applications Division implemented new policies that have strengthened ground- and flight-based research, cooperative science activities with NASA's international partners, and the agency's ties with the National Institutes of Health (NIH).

Our division has initiated an annual divisionwide NASA Research Announcement and restructured the peer review process to raise the scientific standards through greater competition and to provide more efficient, uniform, and systematic proposal evaluation.

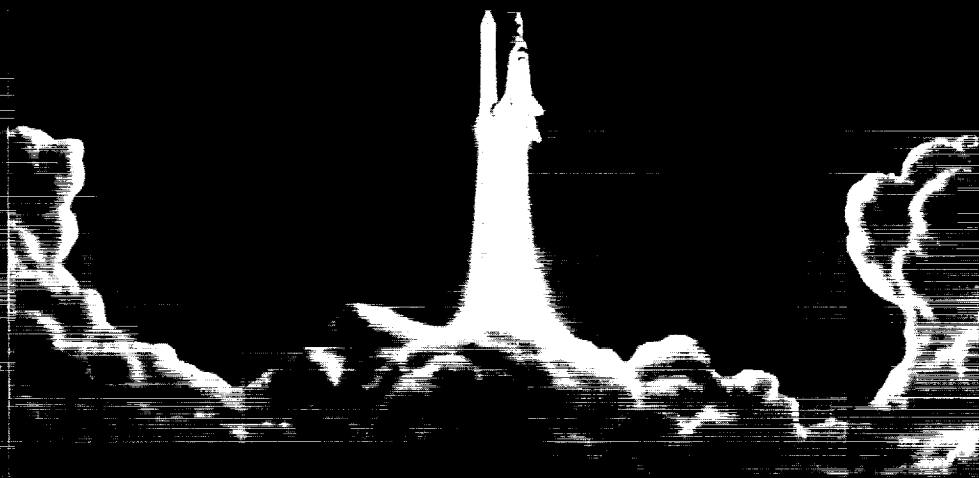
In 1993, we were pleased to award two new NASA Specialized Centers of Research and Training (NSCORTs) to complement our overall ground-based program: one to the University of Texas Southwestern Medical Center for "Integrated Physiology" and the other to Northwestern University Medical School for "Vestibular Research." These awards brought the total number of NSCORTs addressing critical ground-based questions to seven, including a non-NASA Specialized Center on Radiation (in Germany).

Looking to the future, the excitement of discovery will continue with life sciences experiments on the upcoming International Microgravity Laboratory 2 mission, two additional Russian missions (Bion11 and 12), a joint program with Russia on Mir space station, and the Neurolab Spacelab mission to study the effects of microgravity on the nervous system and behavior. In 1994, we will expand our NSCORT Program by creating a joint center with the National Science Foundation to focus on plant physiology. We will continue to develop and use multiple research platforms in orbit, specialized ground-based facilities, collaborative approaches to ensure high-quality space life sciences research, new educational and outreach activities, and means to transfer life sciences technology to the private/commercial sector.

This Accomplishments Document is our Division's annual report to our investors, the American people. It describes how space life sciences research lays the foundation for enabling further human exploration of space and improving U.S. competitiveness, education, and quality of life.

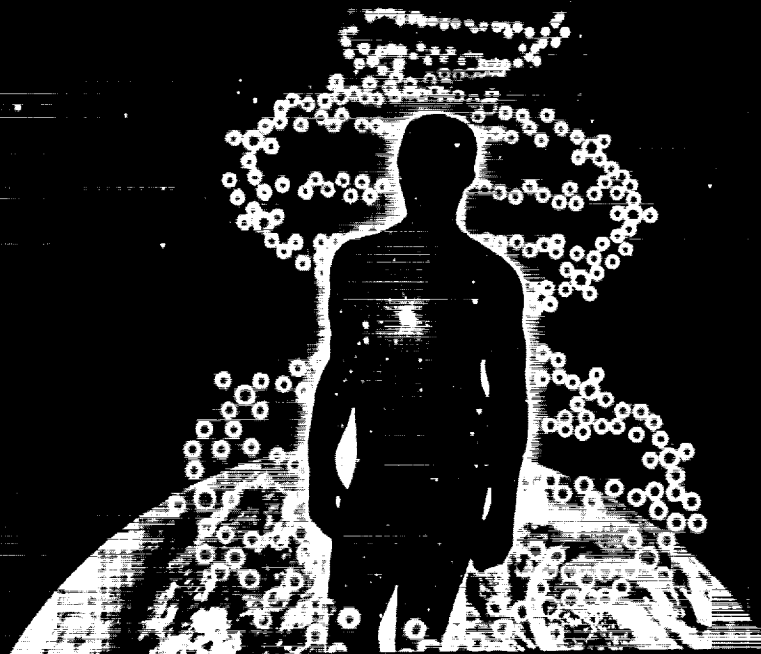
Joan Vernikos, Ph.D., Director
Life and Biomedical Sciences and
Applications Division





*"To myself I seem to have been only like a
boy playing on the seashore, and
diverting myself in now and then finding
a smoother pebble or a prettier shell than
ordinary, whilst the great ocean of truth
lay all undiscovered before me."*

- Sir Issac Newton



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INTRODUCTION

The NASA Life and Biomedical Sciences and Applications Division (LBSAD) serves the Nation's life sciences community by managing all aspects of U.S. space-related life sciences research and technology development. The activities of the Division are integral components of the Nation's overall biological sciences and biomedical research efforts. However, NASA's life sciences activities are unique, in that space flight affords the opportunity to study and characterize basic biological mechanisms in ways not possible on Earth. By utilizing access to space as a research tool, NASA advances fundamental knowledge of the way in which weightlessness, radiation, and other aspects of the space-flight environment interact with biological processes. This knowledge is applied to procedures and technologies that enable humans to live and work in and explore space and contributes to the health and well-being of people on Earth.

The activities of the Division are guided by the following three goals:

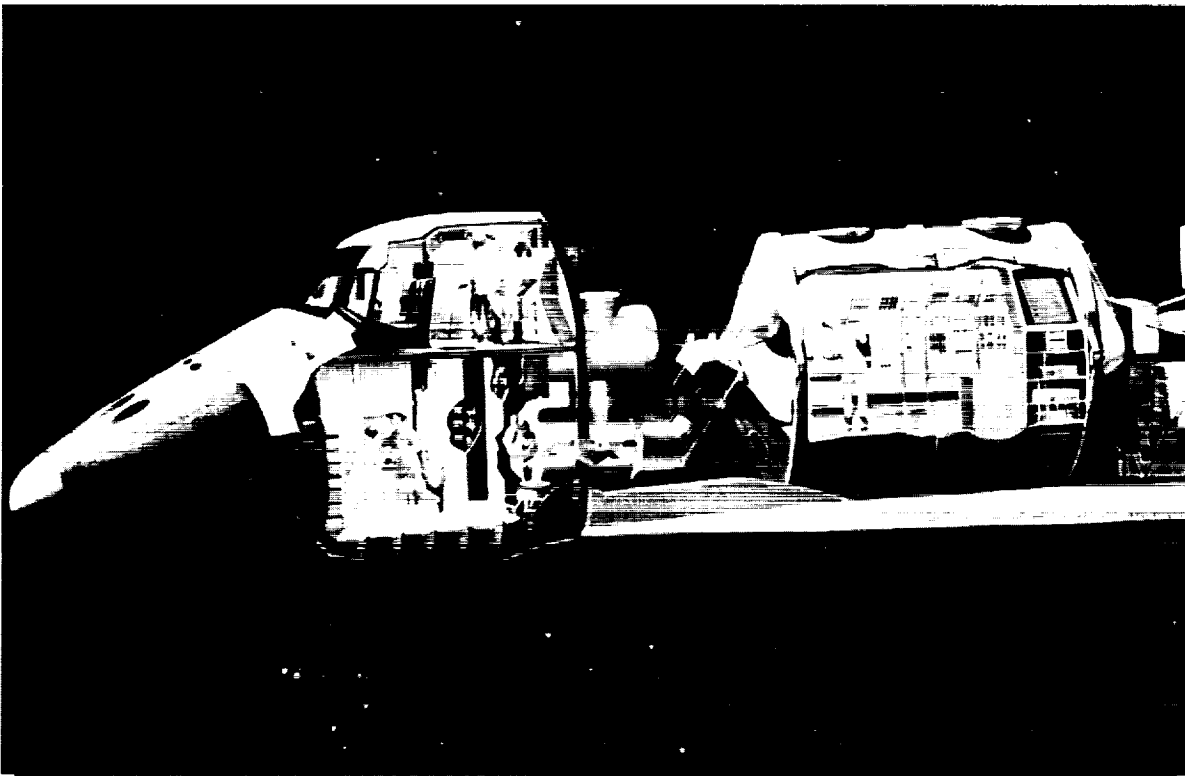
Goal 1 *Use microgravity and other unique aspects of the space environment to enhance our understanding of fundamental biological processes.*

Goal 2 *Develop the scientific and technological foundations for supporting exploration by enabling productive human presence in space for extended periods.*

Goal 3 *Apply our unique mission personnel, facilities, and technology to improve education, the quality of life on Earth, and U.S. competitiveness.*

The Division pursues these goals with integrated ground and flight programs involving the participation of NASA field centers, industry, and universities, as well as interactions with other national agencies and

page i



LBSAD AND EXO BIOLOGY PUBLICATIONS

Published by	Total	Journal articles	Meeting abstracts/ papers	NASA formal papers	Other
1992					
LBSAD	1073	533	462	67	11
Exobiology	319	173	113	14	19
Total	1392	706	575	81	30
1993					
LBSAD	905	452	382	64	7
Exobiology	204	180	13	3	8
Total	1109	632	395	67	15

NASA's international partners. The published work of Division-sponsored researchers is a record of completed research in pursuit of these goals, as reflected in the above table.

During 1993, the LBSAD instituted significant changes in its experiment solicitation and peer review processes. For the first time, a NASA Research Announcement (NRA) was released requesting proposals for ground-based and flight research for all programs. Areas of particular interest to NASA were defined. Proposals due April 29, 1994, will be peer reviewed externally for scientific merit. This annual NRA process is now the mechanism for recruiting both extramural and intramural investigations.

As an overview of LBSAD activities in 1993, this accomplishments document covers each of the major organizational components of the Division and the accomplishments of each. The second section is a review of the Space Life Sciences Research programs —

Space Biology, Space Physiology and Countermeasures, Radiation Health, Environmental Health, Space Human Factors, Advanced Life Support, and Global Monitoring and Disease Prediction. The third section, Research in Space Flight, describes the substantial contributions of the Spacelab Life Sciences 2 (SLS-2) mission to life sciences research and the significant contributions of the other missions flown in 1993, along with plans for future missions. The Division has greatly expanded and given high priority to its Education and Outreach Programs, which are presented in the fourth section. The fifth and final section, Partners for Space, shows the Division's cooperative efforts with other national and international agencies to achieve common goals, along with the accomplishments of joint research and analysis programs.



pace

Life Sciences Research



SPACE LIFE SCIENCES RESEARCH

Using research laboratories in space provides unique opportunities to address fundamental questions in basic biology and physiology; to study the effects of microgravity and radiation on cells, tissue, and organisms; and to apply the results of this research to the improvement of health care, the environment, and the quality of life on Earth. Near-weightlessness encountered on orbit is an opportunity to conduct fundamental research into the importance of gravity to life processes on Earth.

Research on the ground and in space has shown that the absence of gravity changes the normal structure and function of both animals and plants. Studies of humans and animals indicate that, in the microgravity environment, virtually every biological system is affected. Understanding and developing methods to counteract disruptions to biological systems are essential to optimizing the safety and performance of humans during space travel. By understanding how these systems are affected, scientists can develop appropriate and effective countermeasures to minimize the deleterious effects of space travel on crews.

The environmental systems and technologies support programs are designed to enable humans to live and work in space productively and safely. These programs encompass ground-based research and technology development in the areas of radiation health, environmental health, space human factors, and advanced life support. Human factors

research is dedicated to human performance capabilities, human-machine interactions, and the development of technologies that enhance crew productivity. The Environmental Health Program is involved in the application of varied activities and disciplines, such as hazard identification, risk assessment and management, and the development of monitoring techniques and standards to support extended missions on the Space Transportation System (STS, or Space Shuttle) and Space Station. The health and well-being of the crew depend on proper atmospheric composition and pressure and an environment free from accumulated airborne and waterborne toxicants and contaminants. In addition, the spacecraft, crew, and biological specimens must be protected from the hazards caused by ionizing radiation in the space environment. Advanced life support research is focused on developing regenerative life support systems by combining the biological, physical, and chemical processes that produce and recycle the food, air, and water needed to support long-term human missions in space in a safe and reliable manner. This includes bioregenerative life support, physical/chemical life support, environmental monitoring and control, and extravehicular activity (EVA) suits.

NASA research not only helps scientists to understand the effects of microgravity on plants, animals, and humans and the systems and environments that support their health and well-being during space travel but also contributes to scientific and medical research aimed at benefiting people on Earth. In another LBSAD program, the Global Monitoring and Disease Prediction Program, satellite and aircraft remote sensing data are combined with field measurements to globally monitor and predict the risk of the occurrence and spread of communicable diseases on Earth.

In the following subsections, LBSAD-sponsored research and accomplishments in these disciplines during 1993, along with the benefits to Earth's inhabitants, are discussed in greater detail.

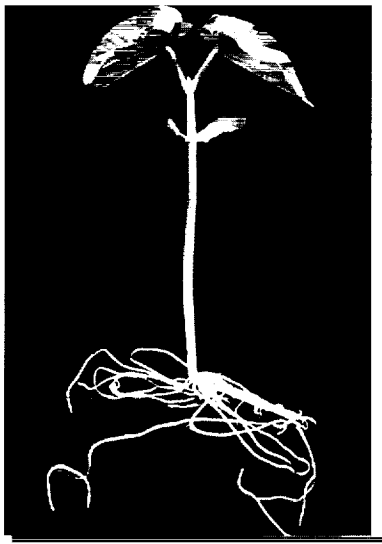


Astronaut David A. Wolf, mission specialist, investigates in-space distribution and movement of blood and gas in the pulmonary system.

Space Biology

The Space Biology Program supports research dedicated to understanding the role of gravity and the effects of microgravity on biological processes; determining the effects of the interaction of gravity and other space environmental factors on biological systems; and using the results of hypergravity, Earth-normal gravity, and microgravity research to advance fundamental knowledge in the biological sciences. Accomplishments in Space Biology during 1993 include the following:

- Gravity sensors in plants help a seedling to distinguish "up" from "down," to emerge from the ground, and to control the direction of growth with respect to gravity. NASA has supported research into the gravity sensing mechanisms of plants and has identified specific (aluminum ion) channels in the cell membrane that cause plants to react to gravity. This research is of particular interest to agronomists on Earth because aluminum ions play a critical role in acid rain effects. Thus, a better understanding of these aluminum ion channels could provide valuable insight



Plants are grown in simulated microgravity in the laboratory, and the responses of their roots and stems are recorded as part of a study to test NASA-developed technology for growing plants in space.

into the acid rain syndrome that negatively affects plants on Earth.

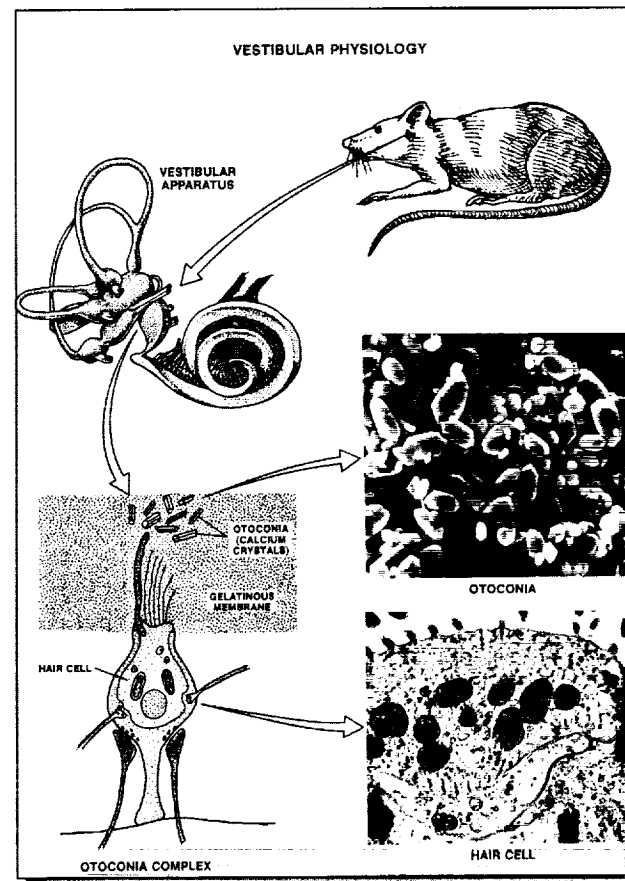
- Research has shown that rapid and coordinated changes of the cell's cytoskeleton and nucleus occur in response to mechanical forces. This indicates that many cell functions are not exclusively controlled through chemical signals received from the cell's deoxyribonucleic acid (DNA), but they may result when a cell responds to force. This new way of viewing cellular response mechanisms has important implications in biotechnology development and health care.
- The Physiological and Anatomical Rodent Experiment (PARE.03), which flew in April 1993 (see page *thd*), has provided results that contribute to the identification of genes that direct bone cells (osteoblasts) to produce more bone. Researchers found a 40 percent decrease in the chemical messages that direct growth in bone-forming cells. They expected this decrease, since space flight is known to slow the rate of bone growth, but an unexpected 300 percent increase in these proteins occurred within 24 hours after return to Earth. With further research, it may be possible for scientists to identify the forces and the genes involved in initiating bone growth and use them to actually stimulate bone formation. This, in turn, could lead to the development of new drugs and therapies for treating human bone disorders.
- Plant biology research was conducted on two Space Shuttle flights, STS-51 and STS-54, in 1993. In these experiments, scientists examined the effects of microgravity on plant reproductive structures and functions, cell wall formation, genetic changes that cause cell wall modifications, and the effects of microgravity on cell division and chromosomal structure and movement. Although data analysis is still underway, preliminary results

indicate that changes occurred in the reproductive structures, particularly in the viability and structure of pollen. Chromosomal abnormalities were also observed.

- Experiments on the vestibular (balance) systems of rats were conducted on SLS-2 and on Earth in a hypergravity centrifuge. Hair cells in the inner ears of mammals and other animals send signals to the brain in response to the presence or absence of acceleration, including gravitational acceleration. Scientists measured the numbers of neural connections between the nerve cells associated with these gravity sensing organs and the brains of both ground-control and space-flown rats. For rats flown and dissected in space, the number of neural connections (in type II hair cells) increased by more than 100 percent after space flight, compared to those of control animals. For animals exposed to hypergravity in a centrifuge, the number of connections decreased by 40 percent. These changes in tissue structure in response to environmental stimuli, called *plasticity*, occur for other reasons on Earth; for instance, a person might experience an increase in muscle mass after weight lifting. This research may help to remedy problems on Earth, such as falls in the elderly, by improving our understanding of how the balance system responds to changes in its environment.

Space Physiology and Countermeasures

This program is focused on improving our understanding of the basic physiological processes of humans and other animals, as



well as the microgravity-induced adaptations that occur during space flight. This knowledge will be used to develop ways to prevent or reduce harmful changes in the physiological processes and thereby optimize crew safety, well-being, and performance in flight and after return to Earth. Studies of humans and animals during space flight have revealed certain changes that resemble those associated with aging and various clinical conditions. For example, the decreased calcification or density of bone (osteopenia) during space flight resembles the reduction in the quantity of bone that occurs in postmenopausal women and elderly men (osteoporosis). Other such phenomena include dizziness upon standing, loss of balance, back pain, and changes in absorption of medications. In 1993, space physiology and countermeasures research was conducted in the following disciplines.

Neuroscience

Neuroscience is the study of the ways in which the brain controls the activities of

humans and other animals. This discipline focuses on the effects of space flight on nervous system functioning and development, the regulation of bodily functions, simple reflexes for automatic responses to a variety of stimuli, the self-perceived position of one's body in the environment, learning and memory, and the ability to perform complex tasks (e.g., locomotion and eye-hand-head coordination). Historically, NASA's interest in neurosensory physiology has been largely attributed to the occurrence of space motion sickness in astronauts and the disorientation and balance problems often associated with exposure to microgravity. Sensory inputs from the inner ear contradict the visual input from the eyes and the information from sensory organs located throughout the body. Accomplishments in neuroscience during 1993 include the following:

- A NASA Specialized Center for Research and Training (NSCORT) on Balance Control/Vestibular Research, jointly supported by NASA and the National Institutes of Health (NIH) National Institute on Deafness and Other Communications Disorders (NIDCD), was awarded to Northwestern University.
- Neurolab, the Spacelab mission dedicated to neuroscience research, which is scheduled for launch in 1998, is on schedule. In response to an Announcement of Opportunity (AO) released in July 1993, more than 160 research proposals in the neurosciences were received from investigators in the United States and around the world. The NIH will conduct scientific peer reviews of these proposals in 1994.
- A program has been developed to precondition crewmembers for the

conflicting sensory signals encountered in space. Subjecting astronauts to external stimuli, the visual and self-motion signal relationships of which differ from those experienced on Earth at 1-gravity, enables them to cope better with the conflicting sensory stimuli encountered in microgravity.

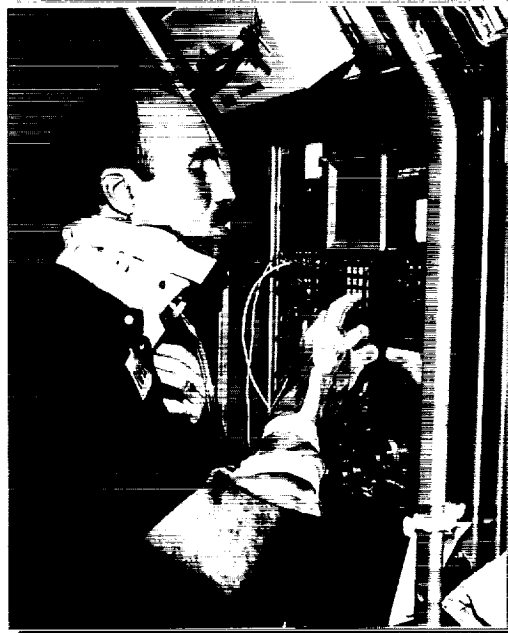
- Ongoing studies are being performed at the Vestibular Research Facility at the NASA Ames Research Center (ARC) using both human and animal subjects. The facility includes a linear sled, which repeatedly moves a test subject forward and backward, and a centrifuge designed for humans. Subjects are exposed to precise angular and linear accelerations under controlled conditions. Medical students in the Ear, Nose and Throat Department at Stanford University Medical School and several NIH-supported investigators from the medical schools at the University of Rochester (New York) and Johns Hopkins University (Maryland) have used this facility to study human acceleration physiology. The information will be used to adapt astronauts to the lack of gravitational stimuli, and for the real-time and postflight analyses of vestibular responses (i.e., those which originate in the inner ear).



Astronaut James Bagan uses the baroreflex cuff in a cardiovascular experiment to study orthostatic intolerance (decreased blood pressure accompanied by a tendency to faint), which is experienced by astronauts upon return to Earth. Clinics around the world use a commercial version of the baroreflex cuff for research and diagnosis.

Regulatory Physiology

Regulatory Physiology is the study of the mechanisms by which humans and other animals adapt to the space environment and respond to internal and external stimuli. Space flight causes the biological process regulating functions, such as metabolism, to adjust and reach a new steady state that reflects the changing needs of the body in microgravity. If adjustments



demand by the environment are too extreme, the safety and performance of astronauts are jeopardized, either in flight or after return to Earth. The research focus is on systems that show marked changes in response to microgravity, including circadian rhythms (biological clock); endocrinology (hormone regulation); renal, fluid, and electrolyte regulation (kidney function); hematology (blood and blood-forming tissues); immunology; metabolism, gastrointestinal function, and nutrition; pharmacokinetics; and temperature regulation. Accomplishments in regulatory physiology during 1993 include the

following:

- An NSCORT in Integrated Physiology was awarded to the University of Texas Southwestern Medical Center. This NSCORT creates opportunities in space life sciences and related technological disciplines at academic institutions and involves students, research scientists, engineers, and the public and private sectors.
- Circadian rhythms are fluctuations in biological and psychological functions of the body that cycle approximately every 24 hours. Disruptions of these rhythms (e.g., "jet lag") can have debilitating consequences. Astronauts must perform tasks during 90-minute day/night cycles and operate on staggered shifts and work/rest cycles, making understanding of circadian rhythms of crucial importance to NASA. Researchers have developed a protocol whereby appropriately timed exposures to very bright light are being used to reset the human circadian clock. This procedure has enabled astronauts to adapt to work schedules required for night launch and early mission performance. On Earth, these methods are being used to combat insomnia and drowsiness in shift workers and, clinically, with patients who suffer from sleep disorders.
- Immunological studies have shown that space flight affects the white blood cells, which are involved in the function of the immune system. Air Force Academy cadets in field training are participating in research to study stress-induced immunoregulatory alterations in humans. Cadets under stress have changes in their immune systems similar to those of space crews. Another



Neurovestibular experiment. Astronaut Rhea Seddon, payload commander, spins the SLS-2 rotating chair with Commander John Blaha as the test subject. These studies will determine how visual cues to the brain are affected in weightlessness, causing disorientation.

study of subjects displaying high and low anxiety has determined that stress alters the functions of macrophages (a type of white blood cell involved in the body's defense against infection).

- A synthetic corticosteroid, 9a-fludrocortisone (9a-FF), was tested on persons subjected to head-down bedrest. Results showed that 9a-FF was effective in completely restoring plasma volume to pre-bedrest levels and reducing the incidence of dizziness and fainting. The cause of this change is currently being investigated.

Musculoskeletal Physiology

Space flights, even for less than 4 days, induce unfavorable changes in the human musculoskeletal system that include reductions in muscle size, strength, and coordination. Prolonged exposure to microgravity affects the skeletal system by making bones more porous and causing a loss of minerals. This results in diminished bone density and increases susceptibility to fracture. Prolonged confinement to bed, aging, or injury can induce changes in bone

similar to those occurring in space flight. Accomplishments in musculoskeletal physiology during 1993 include the following:

- Administration of growth hormones (chemical substances that alter the functions of many of the body's systems), when combined with exercise, were found to prevent the decrease in muscle size that normally occurs in rats when their muscles are unloaded. The use of either hormone or exercise by itself failed to activate the muscle response, thereby demonstrating synergism between exercise and the growth hormone. This approach can be applied clinically to patients who suffer from muscle wasting caused by diseases, broken bones, and conditions that require prolonged bedrest. It may be used to slow or even prevent some of the negative consequences of aging.
- Scientists have identified two substances (bisphosphonates) that increase bone formation in rats. The results hold promise for developing drug treatments to prevent or treat bone loss in humans.

- A portable device was developed for monitoring a person's daily physical activity and the physical forces acting on the legs. This can easily be worn for extended periods. Data analysis from one study has established that a person's activity is correlated with leg bone density. These results will be used to develop countermeasures against bone loss that occurs with aging, osteoporosis, and space flight.
- Laboratory simulation of microgravity employing head-down bedrest was found to produce symptoms of back pain similar to those experienced by astronauts in space, making this a viable model for the study of back pain. Placing humans in a head-down

(approximately 6°) position removes the compressive forces on the bones and cartilage of the spine, allowing them to increase in size because of a shift in fluids.

- A computer model has been developed to show how certain minerals are incorporated into bone, causing them to become rigid. This will facilitate understanding of the reductions in bone mass and strength that occur during exposure to microgravity.

Cardiopulmonary Physiology

During space flight, the heart pumps blood through the blood vessels of the body without the pull of gravity. This causes a variety of changes in the cardiopulmonary system that decrease its ability to function on return to Earth's gravity. This deconditioning is comparable to changes that occur in athletes during the off season, when they stop or reduce their physical activities. The cardiopulmonary deconditioning that occurs during space flight leads to orthostatic intolerance (dizziness or a tendency to faint upon standing). This condition affects virtually every astronaut upon re-exposure to the Earth's gravity and is associated with a failure of the blood pressure control system to maintain blood pressure at a sufficient level. This could have serious consequences for the health, safety, or physical performance of crewmembers, especially in contingency landing situations. To address this problem,



Astronaut Rhea Seddon breathes into the rebreathing unit during the exercise phase of the cardiovascular deconditioning experiment on SLS-2. The results on inflight experiments such as this are applied to alleviate the risk and reduce heart and lung disease on Earth

- Autogenic Feedback Training was successfully used to teach some astronauts to voluntarily increase their blood pressure and, thus, potentially avoid the common problem of orthostatic intolerance upon returning to Earth. This technique shows promise as a drug-

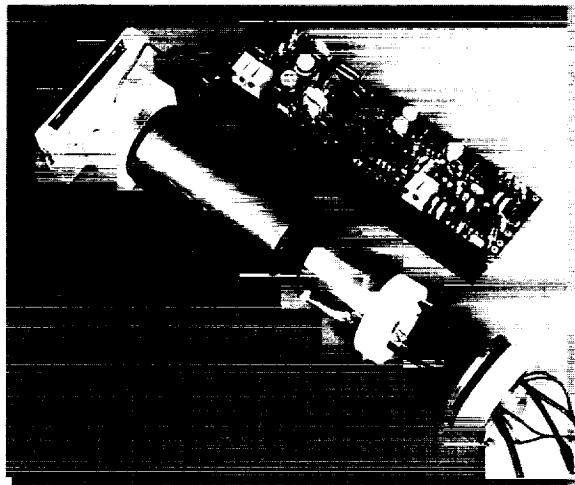
free countermeasure for postflight orthostatic intolerance.

Radiation Health

Protection from the hazards caused by ionizing radiation in the space environment is essential for space exploration. Many of these hazards are ill defined. The Space Radiation Health Program seeks to understand, predict, and prevent deleterious biological effects of the interplanetary radiation environment on humans traveling to and living on other planetary bodies. Accomplishments in Space Biology during 1993 include the following:

- NASA-sponsored research has established a strong link between radiation exposure and endometriosis, a debilitating disease of women and a major cause of infertility. The information gained in this study of female rhesus monkeys will not only aid in understanding the effects of radiation on women and the causes of endometriosis but also in developing more effective treatments.
- Investigators used NASA's state-of-the-art radiation research facilities (simulated weightlessness) to cultivate cancerous cells. The cultured cells showed the greatest resemblance to date to cancerous cells growing in the human body. The ability to culture these cells greatly increases scientists' capacity to study cancer and develop promising therapies.
- NASA sponsored research to develop and test the Tissue Equivalent Propor-

tional Counter (TEPC), which estimates the radiation dose received by an individual cell. The TEPC will fly on the planned Russian satellite mission to Mars in 1994 and is expected to provide unprecedented information about the biologically significant radiation environment in interplanetary space. The same scientists



TEPC

developed another TEPC for use inside the Mir orbital station, which records radiation in an exceptionally broad range of frequencies and can store data for up to three months.

Environmental Health

The health and well-being of crews in the spacecraft depend on an environment with the proper atmospheric composition and pressure, free from accumulated airborne and waterborne contaminants. To achieve this optimum environment, LBSAD conducted environmental health research during 1993 in the following disciplines.

Microbiology

Micro-organisms are integral constituents of life on Earth and will travel with humans on space exploration missions. Although the vast majority of microbes are harmless or even beneficial to humans, some microbial species can cause infectious diseases and allergies. Accomplishments in microbiology during 1993 include the following:

- NASA has developed an Automated Microbial Identification System (AMS-II) that will detect infectious diseases agents in air, water, and on internal spacecraft surfaces. The identification of these agents will allow NASA to take measures to help prevent disease during space flight. AMS-II has broad applications for medical use in remote areas, such as those occupied by Native Americans and in developing countries.

Barophysiology

Decompression sickness, also known as the "bends," is a risk during EVA. This risk could be effectively eliminated by selecting optimum cabin and suit pressures and gas compositions. However, to do so would impose severe penalties on suit mobility (higher suit pressure) or on flammability of materials in the cabin environment (higher oxygen concentration). NASA's approach has been to use studies of humans in hypobaric chambers to define and explore means to reduce the risk of decompression sickness. Accomplishments in barophysiology during 1993 include the following:

- Research during 1993 has brought the number of observations to more than 1000 human exposures at Johnson Space



Pre-cordial doppler monitoring in the altitude chamber. Subjects are tested in hypobaric and hyperbaric chambers to assess the risk of decompression sickness using various combinations of cabin pressure, gas composition, and suit pressure.

Center (JSC), Duke University, and the U.S. Air Force Armstrong Laboratories. Scientists have continued to evaluate the impact of reduced air pressure, increased oxygen prebreathe time, exercise prior to prebreathing and during decompression, and repeated EVA exposures; and they have continued to study the influence of simulated microgravity on decompression sickness.

Toxicology

Space travelers live in a sealed environment, which is the ultimate "tight building." In the spacecraft environment, gases and water must be recycled and purified and airborne particles must be captured. Life support and environmental monitoring systems are critical to the health and well-being of the human crewmembers in this setting.

Accomplishments in toxicology during 1993 include the following:

- NASA-funded research and development projects, which continued in 1993, have led to the development of vastly improved air and water quality sensors and analyzers, air revitalization systems, and means to capture and dispose of airborne particulates. Applications are foreseen for improved environmental control in large commercial complexes; e.g., toxic waste sites and inside large buildings and water treatment plants.

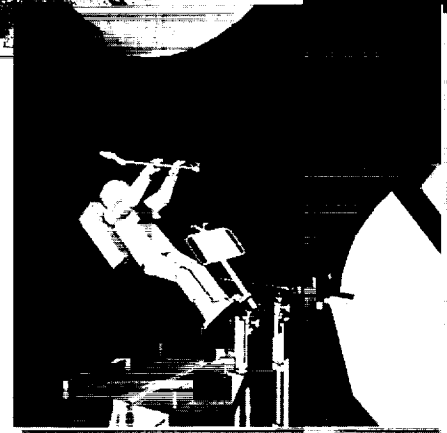
Space Human Factors

The Space Human Factors Program focuses on understanding the psychological, behavioral, and performance adaptation of crewmembers and on developing requirements, protocols, and procedures to ensure their well-being, safety, and productivity in space. Accomplishments in Space Human Factors during 1993 include the following:

- A computerized model that simulates humans performing a variety of tasks in space was developed and applied. Comparisons of computer-generated images with actual photographs taken of astronauts working in space have demonstrated the system's ability to validly model human movement associated with in-flight tasks. These systems are being used commercially by industries and universities in the United States. Potential applications include equipment design, architectural layout, cockpit design, and assembly process timeline scheduling.
- A computerized system was designed to test the hand-eye performance of rhesus



monkeys doing simple tasks and to assess the effects of space flight on their coordination and cognitive performance. Scientists are using this technology to evaluate the unique needs of mentally impaired children. Tests suggest that it may enhance psychomotor coordination, attention, and memory.



Human Factors Engineering uses actual in-flight photographs (above) and computer-generated images (right) to model human movement in performing in-flight tasks.

- An interagency agreement was negotiated and a project was approved for NASA and the French Centre Nationale d'Etudes Spatiales (CNES) to jointly study cross-cultural differences and interactions in small groups in isolation. Studies will begin in Antarctica in 1994.
- The program sponsored a workshop to actively explore the potential use of "virtual environment" in space exploration. Workshop participants recommended the use of virtual environment technology to evaluate the susceptibility to space motion sickness; to test the efficacy of drugs for treating this condition; to enhance observations by astronauts engaged in planetary exploration; to more accurately simulate stressful situations that might be encountered in space (for crew selection); and to provide crews on long-duration missions with respite from the space environment. Once developed, these virtual environment technologies will have broad utility in areas other than space exploration.

Advanced Life Support

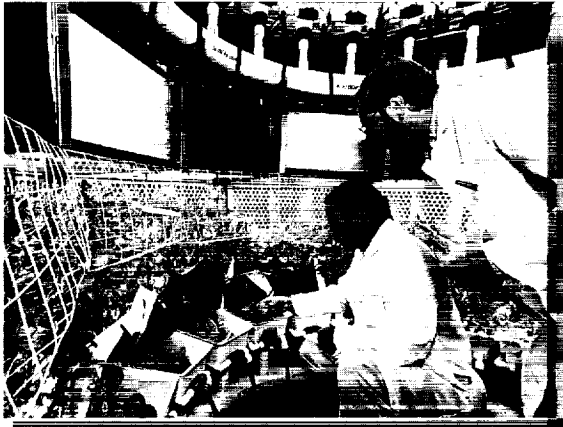
The goal of the Advanced Life Support Program is to develop regenerative life support systems by combining biological, physical, and chemical processes capable of producing and recycling food, air, and water to support long-term missions transporting humans in space in a safe and reliable manner. This research has near-term applications to the Space Station Program, environmental issues on Earth, and long-term applications on future long-duration human missions. Advanced life support research was conducted during 1993 in the

following disciplines.

Bioregenerative Life Support

Research during 1993 was focused on the use of plants and fish to provide life support consumables for humans on future space missions. The observed changes in metabolism and chromosome behavior of plants in space suggest that gravity may act at the genetic level. Knowledge acquired from space-based research may lead to the modification and control of certain genetic functions in food plants. For example, this program may provide information concerning the influence of gravity on plant structure and function, which cannot be obtained from ground-based research alone; and it offers exciting possibilities for the development of Earth-based biotechnologies. In addition, determining the factors controlling cell wall thickness may result in the development of new strategies to modify cell wall formation, upon which agriculture, forestry, and many other industries utilizing plants and plant products depend. Accomplishments in bioregenerative life support during 1993 include the following:

- The Center for Bioregenerative Life Support developed a pasta from legumes that is protein sufficient (i.e., does not need an accompanying meat sauce for balanced nutrition) and genetically engineered rice that is nutritionally balanced and includes essential amino acids.
- NASA-sponsored research has contributed to America's "greenhouse" agriculture industry. This industry is based on growing crops in controlled environments, to provide year-round supplies of fresh crops in areas where climate renders traditional agricultural



Potatoes being harvested from KSC Biomass Production Chamber. All plants grown hydroponically using nutrient film culture.

methods ineffective. Research at Kennedy Space Center (KSC), ARC), and numerous universities has led to the refinement of techniques for growing crops in controlled environments. More nutritious and higher yield crops are being grown hydroponically without the use of pesticides or other organic chemicals.

- Research at Utah State University this year resulted in a wheat crop yield that was almost four times the world record for field agriculture. In addition, the resulting wheat was 50 percent higher in protein content than that grown in the field. This remarkable yield was achieved by varying plant growth factors, such as light, temperature, carbon dioxide level, nutrient flow, and humidity, to achieve maximum wheat yields for potential application to future spacecraft life support systems.
- Research using genetic engineering is improving the quality of food crops. For instance, although rice is the major food

stuff of 40 percent of the world's population, it is low in amino acid lysine, a required nutrient for humans. NASA-funded research introduced the ability to use genetic manipulation to implant the gene that controls this nutrient into rice. Work is continuing to determine whether this characteristic will be propagated in future generations of the rice.

Physical/Chemical Life Support

The focus of this research, which recently has become a part of LBSAD, is on developing highly efficient regenerative physical/chemical life support elements that have minimal resource requirements (e.g., power, consumables, and logistics). These advanced technologies will have numerous applications on current NASA missions, such as the Space Shuttle and Space Station Programs and will enable future long-duration human activities in space. Accomplishments in physical/chemical life support during 1993 include the following:

- A human-rated, ground-based testbed is being established at JSC. Numerous advanced technologies will be tested as an integrated life support system, and an initial 15-day air revitalization system will be tested in 1995.
- The technologies that will be used in the initial life support testbed activities were evaluated at JSC and integrated into the testbed. Personnel from the NASA Jet Propulsion Laboratory provided small sensors and controls.

Monitoring and Control

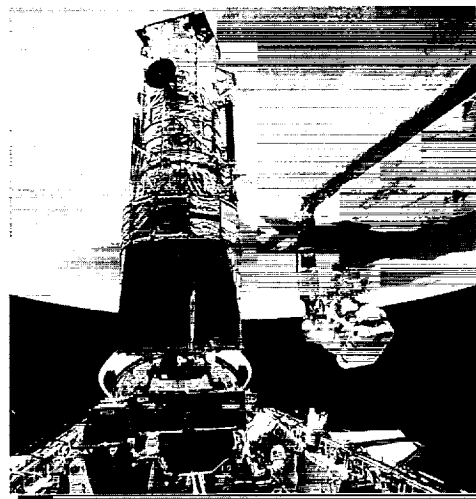
Sensors and controls are required to monitor and control the physical, chemical, and biological components of a spacecraft life

support system. Accomplishments in environmental monitoring and control during 1993 include the following:

- An advanced optical pH sensor was developed and commercialized under NASA-sponsored Small Business Innovative Research (SBIR) activities. It is currently being used in numerous waste water and municipal water supply systems throughout the United States and for hydroponic plant growth by the NASA Bioregenerative Life Support Program.
- A reflectance spectrometer was developed to monitor the availability of nutrients to green plants. This technology has broad applications throughout the plant ecology and environmentally controlled agricultural communities.
- A moisture sensor that detects the presence or absence of the required thin layer of water surrounding the root system of healthy growing plants was developed.
- A microbiological analysis unit was developed for determining the total microbiological and fungal content in nutrient delivery systems with broad applications in waste and municipal water supply systems.

Extravehicular Activity Suits

Human presence is required in space and on planetary surfaces to perform, observe, or supervise certain tasks. While potential technology alternatives, such as robotics and remote manipulation using telepresence, are also under development, state-of-the-art robotic devices are far from the point where an adaptive, autonomous machine can be



Shuttle astronauts, using EVA equipment developed by the advanced Life Support Program, repair the Hubble Space Telescope.

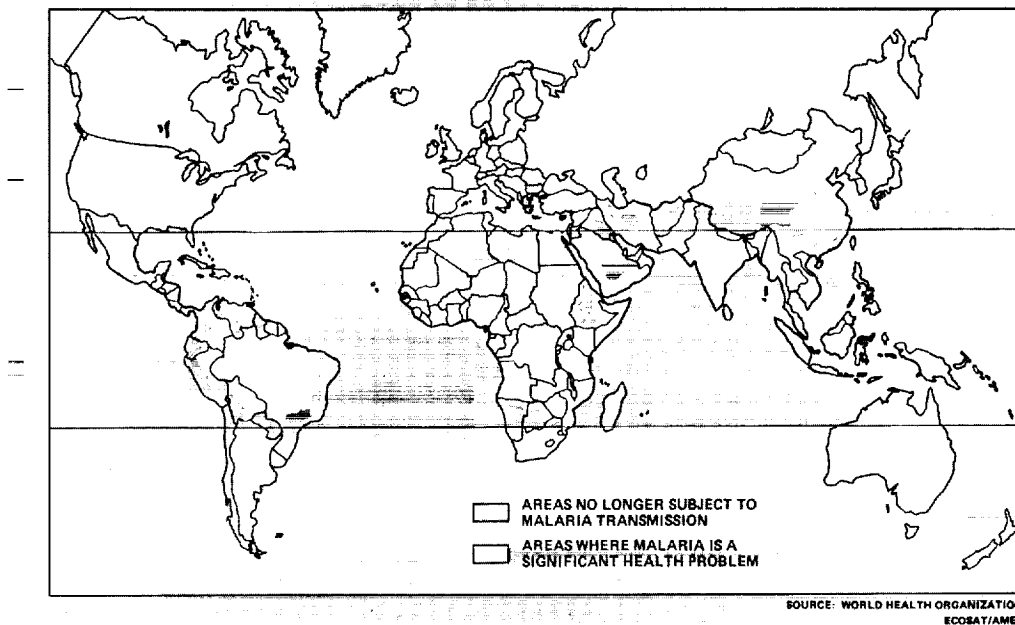
considered a viable means to perform a new, complex task without human supervision. Manual accomplishment is often the most cost-effective means to perform a wide variety of required tasks.

Late in 1993, LBSAD assumed the responsibility to develop EVA system technologies. The Office of Life and Microgravity Sciences and Applications (OLMSA) believes that EVA is an indispensable resource available to human space-flight activities that should be utilized, whenever necessary and feasible, to complete mission-critical tasks. One goal of LBSAD is to provide an EVA system for human beings to carry out research and exploration productively in space for benefits on Earth and to open the door to planetary exploration in the next century.

Global Monitoring and Disease Prediction

It has long been recognized that the spatial and temporal patterns of vectorborne disease transmission are influenced by

GLOBAL DISTRIBUTION OF MALARIA, CIRCA 1982



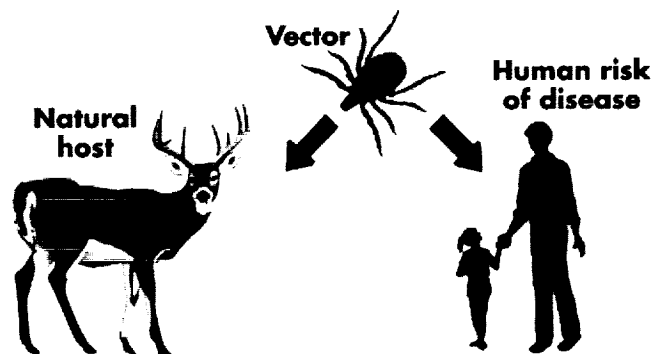
geographical and environmental factors on Earth, such as elevation, temperature, precipitation, vegetation, and human activity. The basic approach of the Global Monitoring and Disease Prediction Program at NASA ARC is to gather satellite and aircraft remote sensing (RS) landscape (environmental) characterizations and combine them with field measurements in a geographic information system (GIS). Then, scientists use this integrated data base to model the spatial and temporal landscape patterns that determine the risk of disease transmission. Accomplishments in global monitoring and disease prediction during 1993 include the following:

- Collaborative research between ARC and other institutions has demonstrated that remote sensing and GIS technologies can be used to identify high anopheline-mosquito-producing rice fields with greater than 90 percent accuracy. The results of this work can serve as a model for the study of rice field mosquito population dynamics that can be applied to other parts of the world where malaria

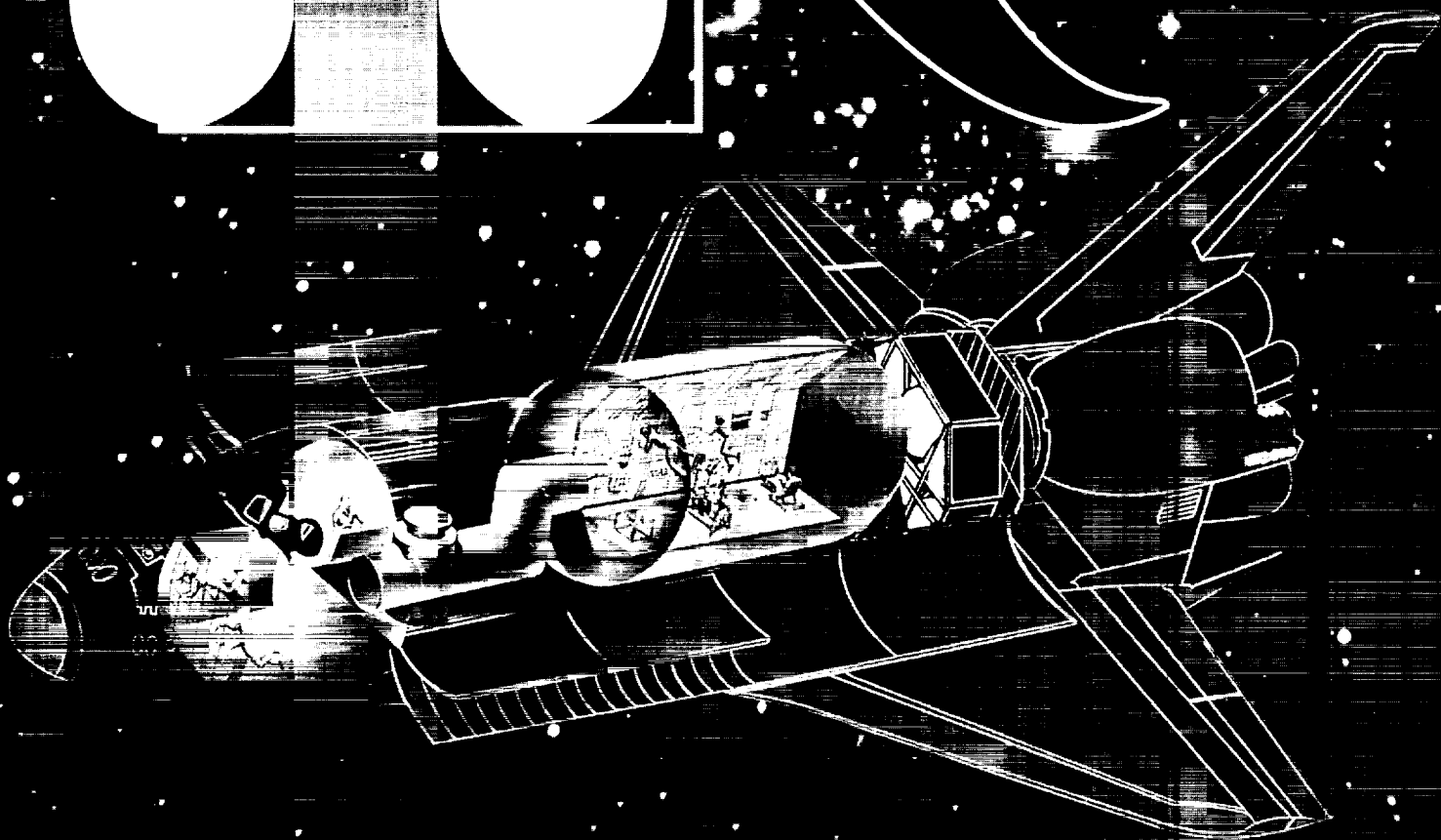
constitutes a serious human health problem.

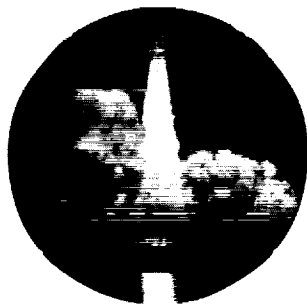
- ARC scientists have conducted research on modeling malaria vector/human contact risk from the *anopheles albimanus* mosquito within villages along the southern coastal plain of Chiapas, Mexico. Landscape elements associated with various stages of the life cycle of the mosquito were identified; i.e., managed pastures, where mosquitos acquire blood meals from cattle; floodable pastures, which provide larval habitats; and trees, which offer resting sites for blood-engorged female mosquitos. The results of discriminant analysis and multiple linear regression using GIS data indicated that the proportions of transitional swamp and floodable pasture surrounding a village are the best indicators of mosquito abundance within a village.
- Lyme disease, which is transmitted to

humans by the bite of a tick that is infected with the disease-causing bacteria, is currently the most commonly reported vectorborne disease in the United States. In a recent study, scientists at ARC identified a relationship between canine seroprevalence rates (CSRs) and landscape elements as an index of human Lyme disease within municipalities comprising Westchester County, New York. (Domestic dogs, which are heavily exposed to tick bites, produce specific antibodies to Lyme disease that can be detected in their blood; the CSR for each municipality is the percentage of sampled dogs that tested positive for these antibodies.) These findings suggest that an RS/GIS technique, which identifies the geographic distribution of this landscape pattern, can facilitate prediction of Lyme disease transmission risk within large suburban regions of northeastern United States that are similar to Westchester County.



Research in Space Flight





RESEARCH IN SPACE FLIGHT

The year 1993 was extraordinarily productive for the LBSAD flight research program. SLS-2, the most successful and longest Spacelab mission to date, was completed. The Division also participated on the German-sponsored Spacelab mission, Deutsche 2 (D-2), and the Russian Cosmos 2229 biosatellite mission. In addition, the Division flew five small payloads on selected Space Shuttle flights, and significant progress was made in planning future research missions in space on the International Microgravity Laboratory 2 (IML-2), Neurolab, Shuttle-Mir, and Space Station.



SPACELAB Life Sciences 2

SLS-2, a mission dedicated to the study of life sciences, was launched on October 18, 1993. This mission provided an unprecedented opportunity to study the effects of space flight on humans and other animals. Many experiments were flown on both SLS-1 (June 1991) and SLS-2 to provide an adequate sample size for statistically significant results. Over the course of the 2-week SLS-2 mission, the 7 crewmembers completed 14 major experiments focusing on the body's adaptation to space and collected more than 5000 blood, bone, muscle, and other tissue samples. In addition, SLS-2 mission specialists accomplished the first in-flight animal tissue collection. Of the 48 rats flown, 6 were dissected on orbit and preserved for later analysis. This procedure provided tissue samples before any readaptation to Earth's gravity could occur.



The studies performed address basic health issues for people on Earth, as well as for space travelers. Eight of the experiments used the crew as subjects, and the other six used the 48 rats. In addition to the 452 timed procedures that were completed, 54 additional unscheduled procedures further enhanced the science return.

Investigators are now analyzing the data from SLS-2, and many of their preliminary findings define new concepts for the role of gravity; e.g., in lung function, the development of anemia and the body's ability to maintain posture and balance. Preliminary results indicate that

- Cardiovascular adaptation to space flight begins almost immediately.
- Differences in the distribution of blood and air in the lungs on Earth were thought to be caused by gravity. However, these differences continued in weightlessness. These and other results

from this experiment have caused a rethinking of how gas is exchanged in the lungs. The knowledge gained from this study will help scientists understand how gas exchange in the lungs is impaired in diseases such as emphysema.

- Analyses of muscle tissue from rats flown on SLS-2 did not indicate tissue damage had occurred. This suggests that the damage observed after previous space flights (where tissue samples were taken after landing) was not caused by weightlessness. Preliminary analyses also indicate that the force and power that muscles generate are reduced after space flight.
- A computerized imaging system developed at ARC is being used to analyze neural tissue acquired on SLS-2. This system allows cell detail to be scanned, digitized, and reconstructed electronically to allow viewing from any angle, or cross-sectioned for interior viewing.



Deutsche 2 Spacelab Mission

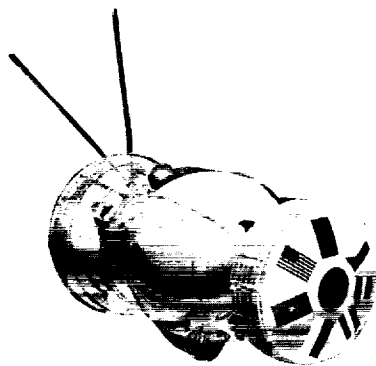
The D-2 mission (launched in April 1993) was the second Spacelab paid for and managed by the German space agency, Deutsche Agentur für Raumfahrtangelegenheiten GmbH (DARA). Although DARA managed the science mission, LBSAD contributed most of the general laboratory equipment. In return, LBSAD received access to most of the life sciences data collected, including the data from DARA, CNES, National Development Agency of Japan (NASDA), and European Space Agency (ESA) experiments.

Life Sciences participation on the D-2 mission represents a significant step forward in international cooperation in space

research. D-2 successfully demonstrated the benefits of pooling international research talent, equipment, and costs. Accomplishments on the D-2 mission include the following:

- Three U.S. life sciences experiments designed to study the effects of space flight on the cardiovascular system and lungs were flown. One experiment investigated the orthostatic intolerance of astronauts after space flight. The experiment confirmed that the reflex system regulating blood pressure becomes less responsive in microgravity, contributing to orthostatic intolerance. The device used to test this reflex is already being used commercially for research and diagnosis in clinics around the world.
- In the second experiment, scientists studied the blood pressure, heart rate, and overall cardiac output of the astronauts both before and after flight. These data are providing information about the mechanisms the body uses to maintain blood pressure. This knowledge is equally useful on the ground for treating patients having difficulty maintaining their blood pressure. Typically low blood pressure is manifested as orthostatic intolerance. These symptoms are common in the elderly, patients who have undergone extended bedrest, and people with certain nervous system disorders.
- The role of gravity in determining the patterns of ventilation in the lung was examined. Under normal gravity conditions on Earth, the lower part of the lung ventilates almost twice as much as the upper part of the lung. Similar to the measurements taken on SLS-1, the in-flight measurements taken on D-2 revealed that regional differences in the blood flow and gas exchange to and from the lungs may not be as gravity dependent as predicted.

These results have already provided new insights into pulmonary perfusion and are helping scientists to understand how gas exchange in the lungs is impaired by diseases such as emphysema.



Cosmos 2229

The eighth in the series of unmanned Russian biosatellites to carry U.S. biological experiments, the Cosmos 2229 (Bion 10) was launched from Russia on December 29, 1992, for an 11-day mission. This Cosmos mission carried two rhesus monkeys in specially designed animal enclosure units. The monkeys had been trained to activate juice and paste food dispensers and to operate a foot pedal so that muscle responses could be studied in flight. For in-flight neurovestibular testing, the monkeys were trained to control their head movements in response to visual stimuli and to respond using a foot lever.

Eleven U.S. investigators participated in Cosmos 2229 in studies of the endocrine system; bone density and bone marrow; circadian rhythms of the brain; skin and body temperature; and metabolic changes in response to space flight. Although data are still undergoing analysis, preliminary results

indicated that, during space flight, the two monkeys showed a decrease in the secretion of growth hormone, significant atrophy in the tibialis anterior muscle, and a long-lasting depression of eye roll movements. Final results are scheduled for publication in early 1995.

Small Payloads

The Small Payloads Program enables the Division to conduct flight investigations in support of its science programs on a regular basis. Most small payloads are designed to operate in Shuttle middeck lockers. Small payload investigations are selected from solicited and unsolicited proposals submitted to the Division. The LBSAD sponsored five investigations under its Small Payloads Program during 1993.

- In January, the third Chromosome and Plant Cell Division in Space (CHROMEX.03) was flown on STS-54. This study focused on the effects of microgravity on plant reproduction, including fertilization, metabolism, and embryo development. Preliminary results showed striking differences



between plants flown on the Shuttle and ground control plants. That is, seed development was aborted at an early stage, the reproductive structures were poorly developed and clustered in the center of the organ, the ovaries were poorly colored and deflated, and the petals of the flowers were only tenuously attached and fell off when touched. In addition, light and electron microscopy revealed distortion and pitting in the root cap.

- On the same mission, the PARE.02 was conducted to investigate the effects of microgravity on the contractile properties of antigravity skeletal muscle and on the endurance properties of the muscle. Preliminary results showed atrophy in both locomotor and antigravity muscles for the flight animals. Significant differences were also found in the functional tests between flight and control animals; that is, the flight animal's muscles could generate neither normal force nor maximum power and required greater stimulation to respond.
- In April, the third Space Tissue Loss (STL.03) experiment was flown on STS-56 to verify changes in cell function observed on two previous Shuttle flights. The results of this investigation will directly apply to improvements in physical trauma care. The STL.03 payload focused on bone strength and structure and the development and functioning of bone-forming cells. The knowledge gained at the cellular level may provide insight into biological mechanisms underlying osteoporosis and other bone diseases in humans on Earth.

- In September, CHROMEX.04 was flown on STS-51. As a reflight of CHROMEX.03, scientists investigated the effects of microgravity on seed production and seed-forming structures of plants that self-pollinated during the mission and began producing seeds. Using a superdwarf variety of wheat, scientists are studying cell division, chromosome stability, root and shoot development, cell wall formation, and gene expression in space. A new nutrient delivery system developed at Washington State University was also evaluated as part of this experiment.

Planning for Future Missions

International Microgravity Laboratory 2



The IML-2 mission is an international cooperative program that assembles the scientific talents from countries around the world to conduct microgravity and life sciences experiments in space. The Space Shuttle *Columbia*, carrying the IML-2 and a crew of seven, is scheduled for launch from KSC in July 1994. LBSAD is responsible for 47 life sciences investigations on the IML-2, which represent an evolution of experiments conducted in ground-based laboratories and on earlier space flights. In many cases, a prime experimental goal is to augment data from previous missions or to lay the groundwork for investigations on future space flights or in ground-based laboratories. Experiment hardware developed by the United States and other nations will be utilized as part of IML-2 mission.

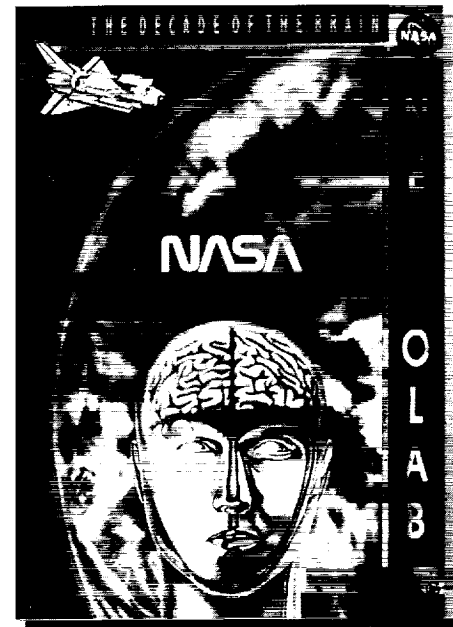
Neurolab

The 1990's have been designated as the "Decade of the Brain," and Neurolab will be NASA's flagship contribution. The LBSAD is working closely with the NIH, the Office of Naval Research (ONR), the National Science Foundation (NSF), NASA's international partners, and the neurosciences community to plan the Neurolab mission, which is currently scheduled for 1998. Neurolab offers the global science community the opportunity to utilize the space environment for investigations that exploit microgravity and features unique to space to increase our understanding of basic processes in neuroscience. It is anticipated that instrumentation and other technology requirements for Neurolab will stimulate the development of a new generation of research equipment for use in the neurosciences.

More than 170 experiment proposals from 15 countries, including the United States, have been received for research on Neurolab. Proposals representing the disciplines of cell and molecular neurobiology, developmental neurobiology, sensory and motor systems, central nervous system homeostasis and adaptation, and behavior are being reviewed for scientific merit, engineering feasibility, and cost.

Cosmos (Bion 11 and 12)

The United States will support one-half of the experiments on the two rhesus monkeys on the unmanned Russian Bion 11 and Bion 12 flights scheduled for June 1996 and June 1998, respectively. French investigators will collaborate with U.S. scientists on these experiments. Investigators from the two countries will conduct musculoskeletal, behavior and performance, regulatory physiology, immunology, and neuroscience experiments on rhesus monkeys.



U.S./Russian Manned Space Activities

With the launch of STS-60 in February 1994, the first Russian cosmonaut flew on a U.S. spacecraft, marking a new era in U.S./Russian cooperation in space. After years of separate and competitive programs, the United States and Russia are now joining forces for the next era in space history.

This scenario will be repeated in a year when another cosmonaut will fly on the Shuttle, followed within months by the launch of a U.S. astronaut on a Russian Soyuz spacecraft for a 90-day stay on Mir. In June 1995, Space Shuttle *Atlantis*, carrying a spacelab module and a new Russian crew will dock with the Russian space station. *Atlantis* will remain docked for 5 days to conduct joint science investigations before returning to Earth with the astronaut and two cosmonauts.

Since summer of 1992, LBSAD has negotiated and developed with its Russian counterparts science protocols detailing the research to be conducted on Mir. The Division's objectives during these first missions are to enhance operational experience in conducting research on an orbital space station, to better characterize the Mir environment relative to life and microgravity sciences research and conduct investigations in these areas, and to identify and imple-

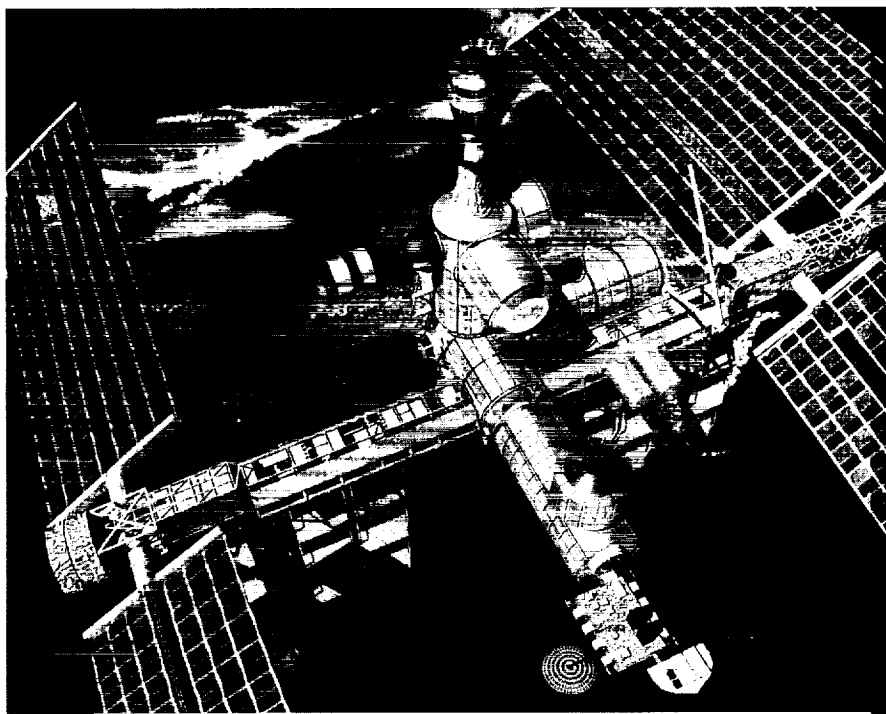
ment technology demonstration efforts that would be applicable to the International Space Station. The United States has negotiated for 2500 kg of hardware to be launched to Mir in late 1994 and 1995 on two pressurized Russian modules, *Spektr* and *Priroda*. This additional hardware will significantly improve the quantity and quality of science data obtained. NASA will solicit experiments through the NRA process. Experiments will be peer reviewed in accordance with established NASA policy.

New Direction on Space Station

The Space Station Program has undergone significant changes in the past year. The program was reorganized, development costs were reduced, and the Russians were invited to participate as an international partner. To coincide with this, the Division has changed its approach to utilizing Space Station and is now planning to develop research facilities, such as the Gravitational Biology Facility and the Human Research

Facility, to contain small, interchangeable payloads that can support a wide variety of research on cells, small plants, aquatic species, insects, and humans. They are designed to provide maximum science return with the restricted resources that are expected to be provided by the Space Station in the early Human Tended Capability years (1998–2000). In addition, LBSAD is working closely with the Space Station international partners to ensure that the life sciences payloads being developed by the United States and its international partners are complementary and to avoid unnecessary duplication.

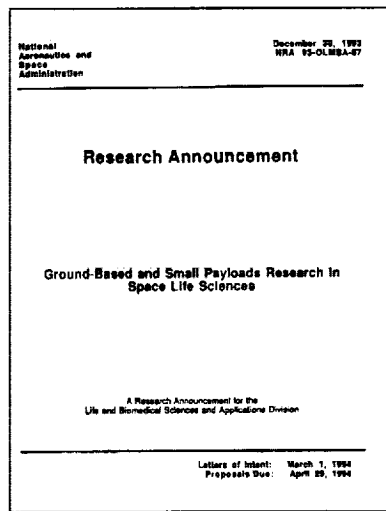
As Space Station reaches Permanent Human Presence Capability (2002) and is able to provide more resources to payloads, LBSAD will bring to the Station more sophisticated facilities, including a 2.5-meter centrifuge, habitat holding systems, and a glovebox, which will allow long-duration gravitational studies on rats and large plants.

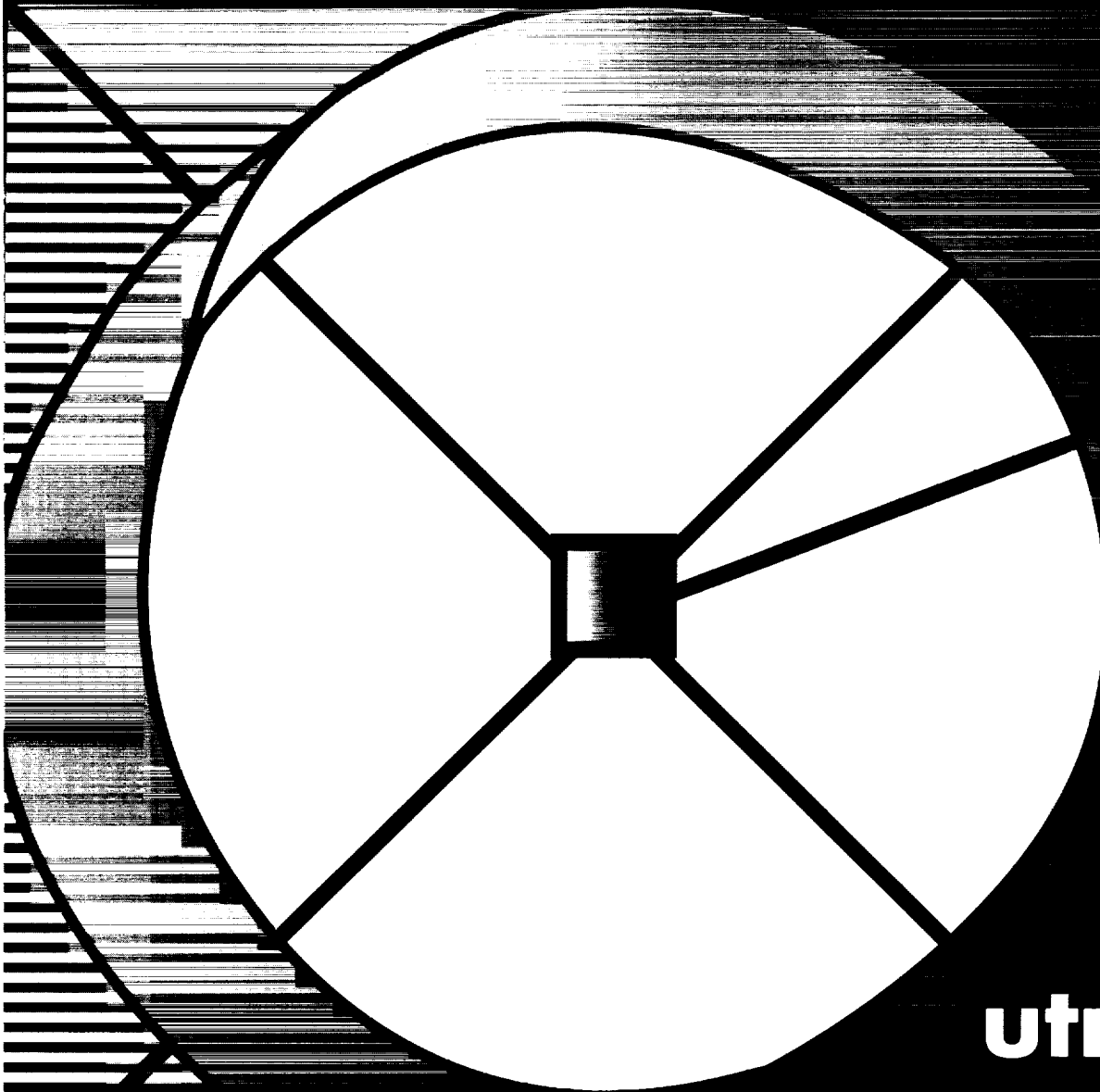


1993 NASA Research Announcements and Announcement of Opportunity Releases

In 1993, LBSAD released five NRAs and one Announcement of Opportunity (AO) to solicit experiments for upcoming flight opportunities:

- **NRA 93-OLMSA-03, Physiological and Anatomical Rodent Experiment 01** – Released in cooperation with the NIH for the study of rodent developmental biology during space flight. Ten investigations have been selected for requirements definition for two flights in 1994 and 1995.
- **NRA 93-OLMSA-04, Musculoskeletal Cell Culture Biological Flight Experiments, NASA/National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)** – Released in cooperation with the NIAMS to study how cells of the musculoskeletal system respond to space flight. Nine investigations have been selected for requirements definition for three flights in 1994 and 1995.
- **NRA 93-OLMSA-05, Flight Research in Plant Biology** – To study how plants and plant cells respond to space flight. Six investigations have been selected for requirements definition for flights in 1994 and 1995.
- **NRA 93-OLMSA-06, Avian Developmental Biology, Flight Experiments for Spacelab Mir 1** – To be conducted jointly with the Russians onboard Mir space station to study the reproduction and development of Japanese quail. Sixteen proposals were submitted and are currently being reviewed.
- **NRA 93-OLMSA-02, Experiments Tissue Sharing Program** – To study biological tissue that has been flown in space but has not yet been analyzed. Proposals are currently being evaluated for selection.
- **AO 93-OLMSA-01, Neurolab Spacelab** – For investigations in the neurosciences on Neurolab, NASA's contribution to the Decade of the Brain. More than 170 proposals were received and are currently being evaluated for selection.





utreach





OUTREACH

The Division is accountable to the American public for its investment in the Nation's space program. LBSAD outreach activities are a part of this accountability process. Outreach efforts involve the education of, and dissemination of information to, the scientific community, students, and the general public about NASA space life sciences activities and programs. This enables them to understand how space life sciences research benefits not only the Nation but individuals as well. Examples of outreach activities in 1993 include, but are certainly not limited to, peer reviews of publications, scientific symposia and workshops, television and radio programs, exhibits and displays, classroom lectures and presentations at scientific meetings, informational brochures and flyers, and the publication of multiple volume books. Special attention is given to formal and informal education and training programs for students with emphasis on attracting women and minorities to careers in space life sciences.

LBSAD Newsletter and Public Relations Materials

The *NASA Space Life Sciences Newsletter* was started in 1992 to provide information about LBSAD activities, accomplishments, and challenges to NASA personnel, the space life sciences community, and the general public. The newsletter has a current distribution list of more than 1100 throughout the United States and foreign countries. Any individual or organization may subscribe to the newsletter free of charge.



Throughout 1993, LBSAD continued to publish the newsletter with issues for Winter 1993, Summer 1993, and Fall 1993. Articles, such as "Cooperative Activities with NASA's International Partners Leading to New Era in the Space Life Sciences," "Space Life Sciences Help to Advance Science and Technology on Earth," and "Trio of Spacelab Missions Probes Role of Gravity in Living Systems," provide the latest information on the topics that are most pertinent to the space life sciences community.

Brochures and information sheets on life sciences programs were prepared and distributed to interested citizens. Topics include NASA Life Sciences Research and Women's Health; U.S./Russian Cooperation in the Space Life Sciences; Telemedicine, Telemedicine in the United States, and Spacebridge to Moscow; Acquiring New Insights into the Processes of Life; The U.S. Civil Space Program; Science and Human Health; NASA's Environmental Health Program; and the SLS-2 and IML-2 missions. Also included in the 1993 public information packet is a full-color lithograph of SLS-2, with a description of the nature and benefits of SLS-2 research on the reverse side.

Presentation at the United Nations

In 1993, a representative of the LBSAD Human Factors Program gave an invited address entitled "The NASA Space Human Factors Program – Putting Humans in Space, Helping People on Earth." In the speech, which was given to the United Nations Committee on the Peaceful Uses of Outer Space, the representative described the work the program is currently supporting and illustrated its important implications for human activity and quality of life.

NASA/NIH Workshop on Research in the Microgravity Environment Related to Cardiovascular, Pulmonary, and Blood Functions and Diseases

According to participants, workshops are the most productive way for NASA life sciences researchers to interact with their colleagues in academia and other government, medical, industrial, and nonprofit institutions. At LBSAD-sponsored workshops, NASA scientists communicate their interests, problems, and insights and describe available research opportunities to colleagues, who, in turn, provide valuable insights and solutions from their own perspective or are motivated to embark on an area of research potentially useful to NASA. One such recent workshop was sponsored jointly with the National Heart, Lung, and Blood Institute (NHLBI) of the NIH. Its purposes were to share current knowledge of the effects of microgravity or altered gravitational conditions on cellular and physiological functions; to discuss how this knowledge might elucidate basic mechanisms and disease processes on Earth; and to recommend further research activities on Earth and in the space environment related to cardiovascular, lung, and blood

diseases. Conclusions and recommendations generated by this workshop will be made public in 1994.

Publication of Book Jointly With Russian Academy of Sciences

In 1975, NASA and the U.S.S.R. simultaneously published English and Russian editions of a three-volume work entitled "Foundations of Space Biology and Medicine," containing chapters written by leading U.S. and Soviet experts. This classic work comprised an exhaustive review of fundamental and applied areas in space medicine, biology, and related fields covering expertise acquired by the scientists of both countries over the first 15 years of space exploration. This edition became a unique source book, providing sound reference material for students and scientists. However, since the first edition was published, many advances have been made in space life sciences research and technology. Thus, another attempt to summarize and analyze knowledge in this area has been initiated. The new five-volume work is the result of the efforts of a joint editorial board presided over by U.S. and Russian editors. Chapter authors from one or more of the participating nations are the leading specialists in their areas.



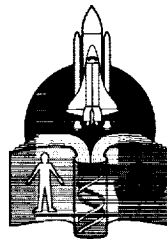
In 1993, after a number of years of work on both sides of the Atlantic, the English version of Volume I of the joint treatise was published. This volume, entitled "Space and Its Exploration," set the stage for the material to follow by describing the historical context and physical environment of space flights, as well as discussing various aspects of the general issue of life in the Universe.

Also, during 1993, scientific and editorial work was completed on the English version of Volume II. Entitled "Life Support and Habitability," it provides comprehensive treatment of the spacecraft environment and the technological and biological systems that have been developed to meet human needs in this unique setting.

Subsequent volumes of this work will be concerned with the effects of space-flight factors on humans and other living organisms and issues associated with the operational support of space flights. The last volume will include extensive reference material relevant to the major topics discussed in the previous volumes.

Education and Training Programs

LBSAD's educational activities were productive in 1993. The Space Life Sciences Training Program (SLSTP) concluded its ninth year of operation and now has more than 300 alumni; the NSCORT Program expanded to include a new Center for Vestibular Research supported jointly by NASA and the NIH NIDCD; and a new program to sponsor research in space physiology, the Graduate Students Research



Program, was started. In addition, a concerted effort was made to focus, integrate, and expand Division programs. A Director for Education and Outreach was appointed, and a strategic planning process was initiated.

In 1993, LBSAD involved hundreds of students and teachers in a spectrum of programs that exposed them to a range of life sciences activities. For some of these students and teachers, this interest may lead to career paths more directly related to the life sciences and engineering; for the vast majority, it will contribute to the understanding of science that is required for civic and economic well-being in a technological society. Some of highlights from 1993 are provided in the following sections.

Space Life Sciences Training Program

The SLSTP is an intensive 6-week summer program at KSC, which utilizes lectures, tours, special projects, and research experience with NASA scientists to teach approximately 40 undergraduate trainees about requirements for life sciences research in space. In 1993, this program successfully completed its ninth year of student training. Jointly sponsored by the Office of Equal Opportunity Programs and the LBSAD at NASA Headquarters, the program has been successful in recruiting and training women (54 percent) and underrepresented minorities (20 percent Black, 10 percent Asian, 1 percent Pacific Islander, and 2 percent Native Americans).

Space Physiology Graduate Student Research Grants

This new program was established in 1993. The program is open to Ph.D. candidates who are national members of the American College of Sports Medicine and are pursuing research relevant to gravitational physiology and the effects of exercise.



NASA Specialized Centers of Research and Training

NSCORT grants provide graduate and postgraduate training by involving students in ongoing research activities. In addition to practical laboratory training, special courses have also been developed. Outreach activities have also been directed toward undergraduate students. As a result of the NSCORT for Vestibular Research established in 1993 at Northwestern University Medical School, which is jointly funded by NASA and NIDCD, the number of students studying balance disorders in the United States increased by 50 percent.

Aerospace Medicine Residency Training Program

This 2-year program conducted at Wright State University School of Medicine, Dayton, Ohio, confers a Master of Science degree in aerospace medicine and prepares physicians for board certification in aerospace medicine. The program provides clinical aerospace training for medical doctors and a third-year rotation at a NASA center. Sixty-four (38 U.S. and 26 international) students have been graduated since 1981.

Space Biology Research Associate Program

This program provides postdoctoral fellowships to conduct research on gravitational and space biology at university laboratories. Fellowships, which are renewable annually, are granted on the basis of competitive, original research proposals. To date, 75 host laboratories have participated in the program, graduating 59 fellows.

Graduate Student Research Program (GSRP)

The GSRP provides a 1-year fellowship (renewable for up to 3 years) for graduate students conducting research relevant to space life sciences. Opportunities exist for students to work in residence at NASA field centers.

Human Physiology in Space

This high school curriculum supplement uses the excitement of space to teach students about physiology. The curriculum supplement consists of student and teacher manuals, slides, and other teaching materials. In 1993, the process of updating the content of the curriculum was begun.

National Research Council Resident Research Associateship

This program provides postdoctoral fellowships at NASA field centers. Twenty-six fellows began their research with NASA in 1993.

Video Teleconferences for Secondary School Teachers

The LBSAD participates in the NASA Education Update for Teachers Videoconference series. The annual series consists of sets of four lectures used in staff development programs for elementary and secondary school faculty. Approximately 2500 teachers viewed these video teleconferences in 1993.

Spacelab Embryology Display and Lesson Plan

Based on the intense interest in the Frog Embryology experiment flown on Spacelab-J in 1992, NASA developed a space science

lesson plan, classroom materials, and a videotape for school children in grades 3 through 6. A portable display and supplementary handout materials were developed for use at public events.

Informal Educational Activities

In 1993, LBSAD participated in a number of informal educational activities, including presentations to primary and secondary school classes; sponsorships of high school and undergraduate interns; and work with other agencies, such as the Smithsonian Institution's National Air and Space Museum.

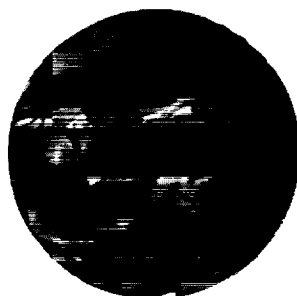
Technology Transfer: Disinfecting Recycled Water

Life sciences personnel at JSC helped to develop a potable water treatment device, which received the NASA 1993 Invention of the Year award in both the commercial potential and NASA benefit categories. The device was originally developed so that astronauts on long space missions could safely recycle their water for drinking. Iodine has long been used to disinfect water, including the water on the Apollo missions, but this device is the first to send the water through a resin bed that is automatically replenished with iodine when the levels get too low.

The device is an attractive alternative to chlorination and other conventional water treatment technologies, because it does not use hazardous gases and cannot over-treat the water. The commercial potential is great, particularly in developing nations, where the need to maintain a safe water supply is critical.

Partners in Space





ARTNERS IN SPACE

The Division is actively involved in partnerships and cooperation with other agencies, national and international, to work toward common goals. This cooperation increases the overall worldwide science return from space life sciences research. Through the joint planning and sharing of a variety of ground- and space-based resources, investigators have access to facilities for collaborating in research, which they would not otherwise have.

NASA has several unique facilities that are available to investigators who are funded by other agencies. These include



- **Vestibular Research Facility**—Centrifuges and other equipment to conduct vestibular research from the cellular to the whole organism level.



- **Biocomputation Center**—Computer capabilities for three-dimensional graphical reconstruction of biological specimens and for computer simulation and modeling of biological systems.



- **Centrifuge Facilities**—Hypergravity research using plants, animals, and human subjects.



- **KC-135**—A specially outfitted airplane that simulates microgravity for approximately 30 seconds.



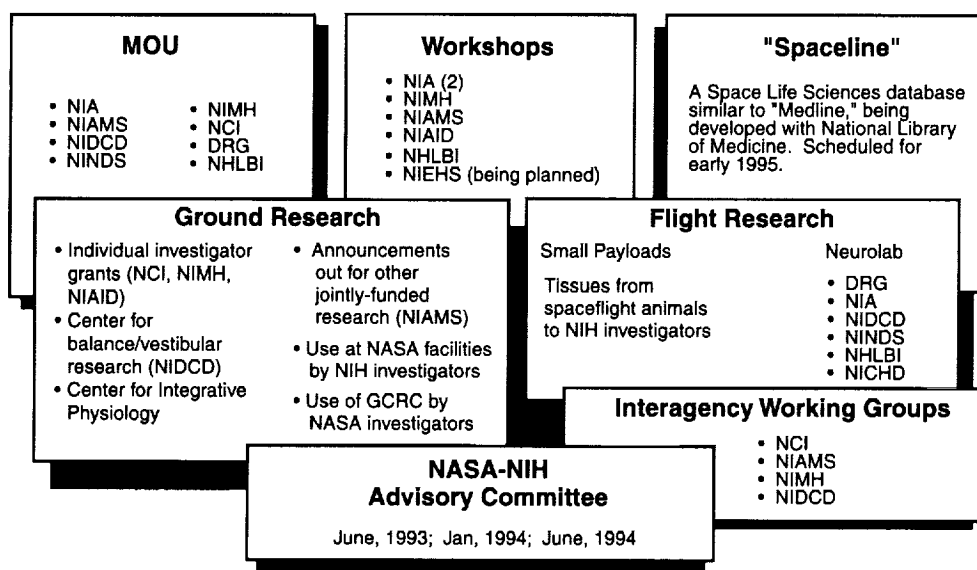
- **Slow Rotating Room**—22-foot-diameter rotating room for conducting vestibular research on humans.

International cooperation began in 1972, when the first formal cooperative program with another space agency—or joint working group (JWG)—was established with Russia. In the 1980s, individual JWGs were also established with the ESA, Canadian Space Agency (CSA), CNES, and NASDA. In 1990, international cooperation was further enhanced by the formation of the International Space Life Sciences Strategic Planning Working Group, a consortium of NASA's international partners. Scientists from the United States have cooperated with their international colleagues on ground-based and flight research. Once the agencies have agreed to work together in certain areas, actual cooperation usually occurs at a scientist-to-scientist level on a more informal, as-needed basis.

Cooperative activities with other U.S. agencies include participation in interagency groups and specific cooperation with individual agencies. Participation in interagency groups includes involvement in various committees and subcommittees: the Human Brain Project; the Arthritis, Musculoskeletal, and Skin Diseases Interagency Coordinating Committee; and the Deafness and Other Communication Disorders Coordinating Committee. NASA has agreements to collaborate with the NIH; the NSF; the U.S. Departments of Defense, Energy, Agriculture, and Commerce (National Oceanic and Atmospheric Administration); and the Environmental Protection Agency.

NASA/ National Institutes of Health

NASA has more ongoing cooperative research with the NIH than any other agency or institution. Cooperative activities include jointly sponsored workshops; jointly funded ground-based research, including large center grants and individual investigator research grants; jointly sponsored flight research, including small payloads and joint participation in Neurolab; and a project with



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the National Library of Medicine to develop a space life sciences data base.

The year 1993 witnessed an exciting growth of momentum in the cooperative activities between LBSAD and several Institutes of the NIH.

- The joint award by NASA and the NIDCD to Northwestern University Medical Center for an NSCORT in the Vestibular Function involving research sites in Chicago, Illinois, and Portland, Oregon, was a highlight in ground-based research.
- The NIAMS issued a research announcement for supplements to its Specialized Centers of Research and projects in osteoporosis for studies related to the effects of space flight on the musculoskeletal function.
- LBSAD also jointly funded individual investigations with several of the Institutes, including the National Cancer Institute and the National Institute of Mental Health (NIMH).
- The following six Institutes are partners in the NeuroLab Spacelab Program:
 - National Institute on Aging (NIA)
 - National Institute on Child Health and Human Development (NICHD)
 - National Institute on Deafness and Other Communication Disorders (NIDCD)
 - National Institute on Neurological Disease and Stroke (NINDS).
- The NIH-NASA agreement signed in 1992 by NASA Administrator Daniel Goldin and NIH Director Dr. Bernadine Healy provided a minimum of five NIH small payloads for flight on the Shuttle each year. Several Institutes worked with LBSAD to plan small payloads and to prepare for NRAs that were released in 1993.
- Jointly sponsored workshops are a useful first step in identifying research areas of mutual interest. Such workshops held in prior years with the NIA, NIAMS, and NIMH have resulted in many of the joint activities implemented in 1993. In May 1993, LBSAD and the National Institute of Allergies and Infectious Diseases (NIAID) jointly sponsored a workshop focusing on "Cooperative Research on Immunology, Infection, and Macromolecular Assembly Related to Microgravity." During 1993, LBSAD also planned and prepared workshops with NHLBI and the National Institute on Environmental Health Sciences to be held in 1994.

- Significant progress was made in the LBSAD-National Library of Medicine project to develop a bibliographic data base of space life sciences research. This data base, called "Spaceline," will be online in 1995.
- At the first meeting of the NASA-NIH Advisory Committee in June 1993, NASA Administrator Daniel Goldin expressed his support for the space life sciences research program and other officials of NASA and NIH spoke about the ongoing activities of the two agencies.

LBSAD considers its cooperative activities with NIH to be an important component of its program to help the Division fulfill its unique mission in the national biomedical research realm and looks forward to expanding and strengthening this cooperation in 1994.

NASA/NSF cooperation will include the joint sponsorship of an NSCORT (plant research) and cooperation on the Neurolab. Cooperative activities include research with the ONR on Neurolab; with the Walter Reed Army Institute of Research on the STL cell culture device; with the U.S. Air Force on physiology, human factors, and environmental health; and with the Armed Forces Radiation Research Institute on radiation health.

Telemedicine Demonstration Project— Spacebridge to Moscow

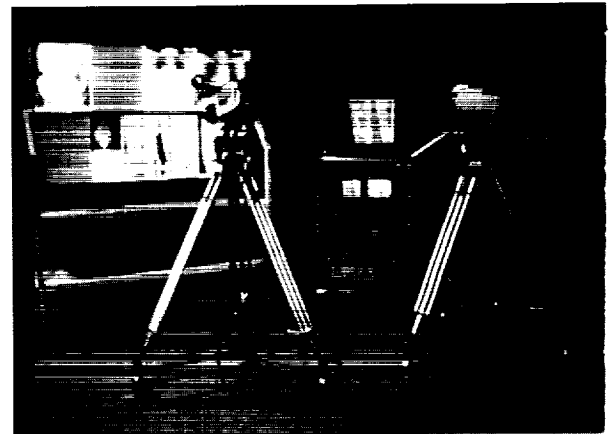


NASA has a long and rich history in telemedicine. In the early days of human space flight, NASA used telemedicine technologies to transmit biomedical data

from astronauts to the ground. In the early 1970's, NASA used its expertise in the Space Technology Applied to Rural Papago Advanced Health Care Program and, in the 1980's, provided assistance (telemedicine) via satellite to earthquake-stricken Armenia.

Currently, NASA is conducting a telemedicine demonstration with the Russians. This international demonstration, called Spacebridge to Moscow, is a multidisciplinary demonstration that links the two diverse medical cultures of the United States and Russia.

Spacebridge to Moscow is being conducted in a variety of clinical disciplines, such as space medicine, internal and preventive medicine, disaster and trauma management, cardiology, surgery, and cancer treatment. The medical centers in the United States and Russia are connected via a communications network, or spacebridge, using two satellites, a U.S. GTE Spacenet GStar II and a Russian Western Satellite Data Relay Network satellite. Each participating site has the capability of two-way, full-motion, color video, and two-way audio. Patients are ensured of confidentiality through the use of encryption devices.





Several institutions in the United States participate with the Clinical Hospital of the Medical Department of the Ministry of Interior in Moscow:

- NASA Headquarters
(Washington, D.C.)
- NASA Medical Operations Branch, Johnson Space Center, in collaboration with The University of Texas Health Sciences Center
(Houston, Texas)
- NASA Lewis Research Center
(Cleveland, Ohio)
- Uniformed Services University of the Health Sciences
(Bethesda, Maryland)
- Latter Day Saints (LDS) Hospital and University of Utah Health Science Center
(a joint effort, Salt Lake City, Utah)
- Fairfax Hospital
(Falls Church, Virginia)

On November 5, 1993, the NASA Spacebridge to Moscow was formally inaugurated in a 2-hour session conducted from the Hart Senate Office Building in Washington, D.C. The program included live consultations between clinicians in Washington, D.C., and Moscow and between clinicians in Washington, D.C., and a hospital in rural West Virginia. During the consultation with Moscow, a pediatric patient, who had been diagnosed as having a Wilms tumor, was presented to clinicians in the Hart Senate Office Building, using a teleradiology/telepathology system provided by the Department of Defense — its Medical Diagnostic Support System.

The telemedicine consultation from Davis Memorial Hospital in Elkins, West Virginia, involved the examination and diagnosis of a 15-month-old cardiac patient. The Spacebridge had been used previously in October of 1993 to provide emergency consultation to individuals who were injured during the political events that occurred in Moscow on October 4 and 5.

As the forerunner of additional telemedicine cooperation between the United States and Russia, the Spacebridge to Moscow will strengthen the scientific and cultural exchange between the two countries, improve medical and communications technologies, foster international medical cooperation, and provide NASA experience in distant health care delivery systems that are vital to health care on Earth and in space.

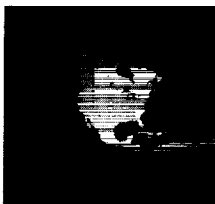
This project was developed by LBSAD and transferred to the Aerospace Medicine and Occupational Health Division late in 1993.

International Space Life Sciences Strategic Planning Working Group

The Division had an active role in the International Space Life Sciences Strategic Planning Working Group (ISLSSPWG) activities in 1993. The ISLSSPWG held two general meetings in 1993, one in Washington, D.C., and one in Cocoa Beach, Florida. These general meetings focused on the development of an International Life Sciences Strategic Plan and discussions on how to best utilize Russian space facilities. In addition, a Technical Interchange Meeting commissioned by the ISLSSPWG was held at ARC in July to provide a comparative assessment of hardware development activities by each ISLSSPWG member agency.

ACRONYMS

AMS	Automated Microbial Identification System	NIA	National Institute on Aging
AO	Announcement of Opportunity	NIAID	National Institute of Allergies and Infectious Diseases
ARC	Ames Research Center	NIAMS	National Institute of Arthritis and Musculoskeletal and Skin Diseases
CHROMEX	Chromosome and Plant Cell Division in Space	NICHD	National Institute on Child Health and Human Development
CNES	Centre Nationale d'Etudes Spatiales	NIDCD	National Institute on Deafness and Other Communications Disorders
CSA	Canadian Space Agency	NIH	National Institutes of Health
CSR	canine seropravelence rates	NIMH	National Institute of Mental Health
D-2	Deutsche 2	NINDS	National Institute on Neurological Disease and Stroke
DARA	Deutsche Agentur fur Raumfahrt-angelegenheiten GmbH (the German space agency)	9a-FF	9a-fludrocortisone
DNA	deoxyribonucleic acid	NRA	NASA Research Announcement
ESA	European Space Agency	NSCORT	NASA Specialized Center of Research and Training
EVA	extravehicular activity	NSF	National Science Foundation
GIS	Geographic Information System	OLMSA	Office of Life and Microgravity Sciences and Applications
GSRP	Graduate Student Research Program	ONR	Office of Naval Research
IML	International Microgravity Laboratory	PARE	Physiological and Anatomical Rodent Experiment
ISLSSPWG	International Space Life Sciences Strategic Planning Working Group	RS	remote sensing
JSC	Johnson Space Center	SBIR	Small Business Innovative Research
JWG	joint working group	SLS-1, -2	Spacelab Life Sciences 1 and 2
KSC	Kennedy Space Center	SLSTP	Space Life Sciences Training Program
LBSAD	Life and Biomedical Sciences and Applications Division	STL	Space Tissue Loss
LDS	Latter Day Saints	STS	Space Transportation System (Space Shuttle)
NASA	National Aeronautics and Space Administration	TEPC	Tissue Equivalent Proportional Counter
NASDA	National Space Development Agency of Japan		
NHLBI	National Heart, Lung, and Blood Institute		



Sciences Research in the United States

This listing includes some U.S. Government organizations, academic and research institutions, and commercial/ industrial firms conducting NASA life sciences research.

ARIZONA

University of Arizona

CALIFORNIA

Anacapa Sciences, Inc.
Lawrence Berkeley Laboratory
NASA Ames Research Center
NASA Jet Propulsion Laboratory
San Diego State University
San Jose State University
University of California at:
Berkeley
Davis
Irvine
Los Angeles (UCLA)
San Diego
San Francisco
Veteran's Administration Medical Center,
San Francisco

COLORADO

Colorado State University
University of Colorado

CONNECTICUT

University of Connecticut
Yale University

DISTRICT OF COLUMBIA

National Research Council
Naval Research Laboratory

FLORIDA

Florida A&M University
NASA Kennedy Space Center
University of Florida
University of Florida College of Medicine
University of Miami
University of Miami School of Medicine

GEORGIA

Georgia State University
University of Georgia

ILLINOIS

Northwestern University
University of Illinois, Champagne-Urbana

INDIANA

Indiana State University
Indiana University
Purdue University

KANSAS

Kansas State University

KENTUCKY

University of Louisville
Wenner-Gren Research Laboratory

LOUISIANA

Louisiana State University
Tulane University

MAINE

Bowdoin College

MARYLAND

Armed Forces Radiological Research Institute
Computer Sciences Corporation
Johns Hopkins University
NASA Goddard Space Flight Center
National Council on Radiation Protection
National Institutes of Health
University of Maryland at
Baltimore
College Park
Uniformed Services University of the Health Sciences
U.S. Department of Agriculture at Greenbelt

MASSACHUSETTS

Brandeis University
Harvard University
Marine Biology Laboratory
Massachusetts Institute of Technology
Woods Hole Oceanographic Institute

MICHIGAN

Michigan State University
University of Michigan

MINNESOTA

Bemidji State University

MISSOURI

State Louis University
Washington University

MISSISSIPPI

University of Mississippi, Jackson

MONTANA

Montana State University

NEBRASKA

University of Nebraska

NEW JERSEY

University of Medicine and Dentistry of NJ

NEW MEXICO

Lovelace Medical Foundation
University of New Mexico

NEW YORK

Brooklyn College
Columbia University
Cornell University
Mount Sinai Medical Center
New York University
State University of New York at
Buffalo
Stony Brook
University of Rochester

NORTH CAROLINA

Duke University
East Carolina University
North Carolina State University

OHIO

Case Western Reserve University
Kenyon College
Miami University
Ohio State University
Ohio University
Wright State University

OKLAHOMA

Cytodiagnostics, Inc.

OREGON

Oregon State University
Good Samaritan Hospital
Neurological Science Institute, Portland
Oregon State University

PENNSYLVANIA

Micro G Research
Pennsylvania State University
University of Pennsylvania
University of Pittsburgh

RHODE ISLAND

Miriam Hospital, Brown University

TENNESSEE

University of Tennessee
Vanderbilt University

TEXAS

Arlington Medical Center
Armstrong Laboratory, Brooks AFB
Baylor University
Methodist Hospital
NASA Johnson Space Center
Rice University
Southwest Research Institute
Southwestern Medical School
University of Texas at
Austin
Dallas
Galveston
Houston
San Antonio
University Space Research Associates

UTAH

University of Utah
Utah State University

VIRGINIA

East Virginia Medical School
NASA Langley Research Center
NASA Lewis Research Center
Naval Hospital
Virginia Commonwealth University

VERMONT

University of Vermont

WASHINGTON

University of Washington
Washington State University
Washington University

WISCONSIN

Marquette University
Medical College of Wisconsin
University of Wisconsin, Madison
University of Wisconsin Medical School

WEST VIRGINIA

Marshall University
West Virginia University

The Life and Biomedical Sciences and Applications Division gratefully acknowledges the contributions of the following persons, who furnished material or assisted in writing this report; Duncan Atchison, Elise Blaese, Mary Lou Burnell, Gary Coulter, Charles Doarn, Robert Dunning, Glenn Ferraro, Mary Anne Frey, Doug Gruendel, Carl Guastaferrero, Bruce Hather, Carla Howard, Mike Jablin, the JSC Public Affairs Office, Laura Lewis, Robin Maggio, Derrick Murray, Ed Rezak, Barbara Rogan, Josh Singer, Perry Stabekis, Lydia Stone, and Jim Wilson. Special thanks go to the editorial staff – Mary Lou Burnell, Editor; and Carla Howard, Graphics Specialist, who designed and prepared this document for publication.

